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TECHNICAL REPORT
68-65-FL

EFFECT OF HEADSPACE OXYGEN ON THE QUALITY OF FREEZE-DRIED BEEF AND CHICKEN STEW

by
J. M. Tuomy, Larry Hinnergardt
and R. L. Helmer

May 1968

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

US ARMY MATERIEL COMMAND

Food Laboratory
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Natick, Massachusetts 01760

FOREWORD

The adverse effect of oxygen on freeze-dried foods has been recognized from the beginnings of the Armed Forces program to develop freeze-dried rations. It has been accepted generally that a maximum limit of 2 percent oxygen in the headspace gas or an equivalent vacuum is sufficient to protect foods and is practical to obtain industrially. This limit is currently standard in Armed Forces specifications. Storage tests as well as field usage have confirmed the validity of this requirement. However, foods are very complex and the response of foods to oxygen varies widely from item to item. Since packaging with low oxygen is expensive and is an inspection problem as well, studies on individual items are necessary to establish the oxygen "tolerance" of each item.

The items in the Food Packet, Long Range Patrol represent a new family of freeze-dried combination foods that are dried as complete items rather than as separate ingredients. Therefore, this study was initiated to determine the oxygen response of various types of products made this way. This report covers two of the eight items in the Long Range Patrol packet: Beef and Chicken Stews.

The work was performed under project 1J6-24101-D553, Food Processing and Preservation Techniques, Quality Parameters of Dehydrated Food.

The work of Mr. Otto Stark, US Army Natick Laboratories, in planning and conducting the chromatographic analyses for this study is gratefully acknowledged.

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ABSTRACT

To study the effect of headspace oxygen on quality, beef and chicken stews freeze-dried after formulation were packed in cans with vacuums ranging from 30 to 0 inches. The cans were stored at 100° F and tested at intervals by a technological taste panel for 24-weeks. In addition, the headspace gas in each can was analyzed by chromatographic means for oxygen and carbon dioxide and the rehydration ratio determined at each interval.

Almost all of the oxygen available to the product was taken up during the 24-week period although at a slightly slower rate by the chicken stew than by the beef stew. Panel ratings for flavor and odor corresponded to the quantity of oxygen absorbed by the product with lower ratings being obtained with the higher oxygen uptake figures. No correlation was found between the rehydration ratio and oxygen uptake.

The results emphasize the importance of limiting headspace oxygen in military specifications for freeze-dried products. The beef and chicken stews may not absorb oxygen as rapidly and thus not deteriorate as rapidly as some freeze-dried products, but in time will absorb enough oxygen, if it is available, to become unacceptable.

INTRODUCTION

The adverse effects of oxygen on the quality of freeze-dried foods have been of concern from the beginning of the Armed Services program for the development of new freeze-dried operational rations. A large number of in-house storage studies have shown that most freeze-dried foods are sufficiently stable for military use if, among other things, the oxygen is less than 2 percent in the headspace gas when the products are nitrogen packed or vacuum packed at 28 inches vacuum or better. Furthermore, a 2 percent oxygen limitation was met by industry without too much difficulty when the initial procurements were made to field test the new rations. Subsequent procurements amounting to many thousands of pounds of freeze-dried meats for field as well as garrison use have confirmed the validity of the storage study results. Almost all current military specifications for freeze-dried meats contain a requirement for nitrogen packing with a maximum oxygen content of 2 percent in the headspace gas.

Percentage oxygen in headspace gas is a convenient measurement, but does not give a complete picture since it does not relate the quantity of product with the actual quantity of oxygen present unless product and headspace are constant. The trend in ration design is toward flexible packaging with vacuum rather than rigid containers with gas packaging. Percentage oxygen in the headspace is therefore meaningless and any oxygen limitation will have to be expressed as a minimum vacuum or as a maximum quantity of oxygen available to the product. The validity of an absolute requirement of 2 percent of less oxygen for all freeze-dried products has been questioned by some manufacturers.

Sharp (1953) mentions that dehydrated meat must be kept in an oxygen-free atmosphere. Harper and Tappel (1957) point out that a large quantity of oxygen is absorbed during the deterioration of freeze-dried beef, but do not draw any conclusions as to a practical limitation on oxygen to insure storage stability. Wuhrmann et al. (1959) and Tappel et al. (1957) note that the storage stability of freeze-dried foods is improved when the foods are packed in a nitrogen atmosphere. Olcott (1962) states that there is a rapid loss of palatability when freeze-dried meat and fish are stored in oxygen or air. Smithies (1962) states that in an oxygen-free atmosphere, freeze-dried meat products suffer only a slow change in quality over periods of several months and air storage of these products can bring about spectacular decreases in rehydration. Thompson et al. (1962) states that three major factors determine the type and extent of deterioration reactions in freeze-dried foods: residual moisture level, headspace oxygne content, and duration of storage at elevated temperatures. Roth et al. (1965) investigated the deterioration of freeze-dried beef, chicken, carrots, and spinach, reporting that exposure to oxygen appeared to be the most significant factor in degradation of freeze-dried products stored at elevated temperatures. These investigators also reported that the specific biochemical and biophysical properties of each food determine its ability to tolerate some variation in residual moisture, headspace oxygen, and duration of storage at elevated

temperatures. Hanson (1961) reported oxygen tolerances for various foods using as a tolerance the ratio, quantity of oxygen available to the weight of product, resulting in the product being just acceptable after 10 weeks storage at 25° C. Tolerances for meat and fish products ranged from 0.1 to 1.0 mg of oxygen per gram of dry food.

In redesigning and improving the Packet, Subsistence, Long Range Patrol, which is carried by the individual soldier and consists of 8 different freeze-dried main menu items, it was decided to dehydrate the prepared item rather than mix dehydrated ingredients and to use vacuum packaging in a flexible pouch. Development studies showed that the products were sufficiently stable for the intended purpose when dried to less than 2 percent moisture and held at a vacuum of 28 inches or better. However, no information was available as to the effect of lower vacuum which would simplify operations during volume production. Therefore, this study was initiated to determine the effects of various vacuums on the organoleptic qualities of two main component items, when they are held at elevated temperatures.

EXPERIMENTAL METHODS

The beef and chicken stews were made in accordance with Interim Purchase Description IP/DES S-36-6 Packet, Subsistence, Long Range Patrol, dated 20 April 1966. Formulas used are shown in Table 1. The total amount of each stew needed for the investigation was made in a single batch and dehydrated in one freeze dehydrator chamber in order to minimize processing variations. Dehydration was to less than 2 percent moisture and the vacuum on the chamber was broken with nitrogen. Freeze dehydration conditions were 120° F plate temperature with radiant heating and a pressure of 400 microns. Packaging was in No. 2-1/2 cans and was accomplished as soon as possible after the dehydrator was opened.

Twenty-five cans each containing 125 grams of product, which filled the can to the top, were closed at each vacuum. Vacuums used were 30, 28, 26, 24, 22, 20 and 0 inches. The cans closed at 30 inches were evacuated three times with 30 second dwell each time and flushed back with nitrogen the first two times. The other cans were closed as soon as the gauge indicated the required vacuum. The vacuums attained corresponded to approximately 1, 2, 3.5, 5, 6, 7 and 21 percent oxygen if the cans had been gas packed. The cans were then stored at 100° F and 5 cans of each vacuum withdrawn for evaluation at 0, 2, 4, 12, and 24 weeks. 100° F was chosen as the storage temperature since one of the standard requirements used in development work for freeze-dried meat ration items is that they must be acceptable after one year storage at this temperature.

Headspace gas analysis was performed by chromatographic means in accordance with the procedure outlined by Bishov and Henick (1966). Prior to analysis the cans were brought to room pressure with nitrogen and allowed to equilibrate overnight. Sample size was 250-500 μl. Experience with this method in-house would indicate an anticipated error for the method of approximately ± 0.25%. Results for the 5 cans of each level were averaged for reporting purposes.

Total headspace volume in the can was determined by compressing 125 grams of product in a laboratory press at 2000 pounds for 10 seconds and subtracting the volume of the resulting bar from the total volume of the can. It was recognized that this method is not the most accurate available, but considering that the volume of headspace is so large in comparison with the absolute volume of the product and that evaluations were to be made with a taste panel, any resulting error was considered insignificant.

Tast panel evaluation was made by a 10-member technological panel rating the product on a 9-point scale for flavor, odor, and texture where the highest number was the most acceptable flavor, odor, or texture. The same panel members were used for each evaluation. Product was rehydrated with 180° F water for 5 minutes for tasting. Product in the cans used for the chromatographic analyses was used for the panel evaluation.

Rehydration value was obtained by rehydrating 125 grams of product with water at 180° F for 5 minutes, draining the product for 1 minute on a wire screen with 1/8 inch square openings and reweighing. Rehydration ratio was calculated as weight of rehydrated product divided by weight of dry product.

RESULTS AND DISCUSSION

Analysis of variance of vacuum and storage time versus panel ratings is shown in Table 2. These results confirm that oxygen and storage time at evaluated temperatures are two important factors in determining the deterioration of freeze-dried foods (Thompson et al., 1962). This is true for flavor and odor in particular. However, the results for texture are not so distinct. This could be expected since texture in a stew is more difficult for a panel to assess than are flavor and odor.

Tables 3 and 4 show the average flavor, odor, and texture scores for the 24-week period. Almost all of the oxygen available to the products was taken up by the end of the 24-week period. It should be noted both that the oxygen uptake was gradual and that the rating values decreased as the oxygen uptake increased. Thus, quality of the product was time dependent as well as oxygen dependent. The results indicate that chicken stew took up oxygen at a slower rate than the beef stew. The acceptance ratings also decreased at a slower rate. Informal in-house observations have indicated that some freeze-dried meat products deteriorate more rapidly than did the two stews. By the end of the 24-week period both products received very similar ratings and the regression equations (Fig. 1) indicate that the uptake of an equivalent amount of oxygen resulted in equivalent panel results with each product. The results are of the same magnitude as those shown by Hanson (1961) for beef and vegetable stew. There is no question that if the products are exposed at 100° F to an excess of oxygen the quality will deteriorate to the point of being unacceptable within a few weeks. Only traces of carbon dioxide were found at any time during the 24-week period.

Correlation coefficients and linear regression equations for oxygen used versus the panel ratings are shown in Table 5. The correlations are excellent except for texture rating of chicken stew. Furthermore, while the slopes of the equation plots for odor and flavor (Fig. 1) are different, the slope for flavor for beef stew is almost identical to that for chicken stew. The same holds true for odor.

Rehydration ratios showed no correlation with vacuum, oxygen used or time in storage. This does not agree with the findings of Smithies (1962) which probably can be explained by the fact that this investigation was concerned with cooked stews rather than a single meat item. However, it should be noted that no good correlations of rehydration with storage time or oxygen have been found in any of the in-house studies made by these Laboratories.

The results of this study clearly indicate the need for rigid oxygen control measures for packaging freeze-dried rations to be used by the Armed Forces. This means that much more work is needed on flexible packaging of freeze-dried rations to insure that the low oxygen level needed is both obtained initially and preserved through the rigors of Armed Service distribution and use. The task ahead includes working out specification requirements that are (1) industrially feasible to comply with, and (2) fully responsive to the military need for high quality freeze-dried rations, capable of use in any part of the world.

Table 1. Formulas used in the preparation of the Beef and Chicken Stews

Ingredient	Beef Stew	Chicken Stew
	Percent by weight	
Beef, cooked, diced	38.8	----
Chicken, cooked, diced	--	29.0
Potatoes, raw, diced	16.0	21.0
Peas, raw, frozen	3.3	4.5
Carrots, raw, diced	4.6	5.0
Water	32.0	32.0
Vegetable oil	2.0	2.5
Seasoning mix	3.3	6.0
	100.0	100.0

Seasoning Mix Ingredient	Beef Stew	Chicken Stew
	Percent by weight	
Soup and Gravy Base, Beef	50.0	--
Soup and Gravy Base, Chicken	--	25.0
Starch, instant	36.0	30.0
Salt	7.0	10.6
Onion powder	2.0	--
Pepper, white	0.9	0.6
Onions, dehydrated	4.1	3.4
Poultry seasoning	--	0.21
Monosodium glutamate	--	0.1
Non-fat dry milk	--	30.0
Garlic powder	--	0.09
	100.0	100.0

Table 2. Analysis of Variance Results

Factor	Flavor	Odor	Texture
Beef Stew			
Vacuum	**	**	*
Storage time	**	**	*
Vacuum & Storage time	**	*	n.s.
Chicken Stew			
Vacuum	**	**	n.s.
Storage time	**	**	n.s.
Vacuum & Storage time	**	**	n.s.

** Significant at the 1% level
* Significant at the 5% level
n.s. Not significant

Table 3. Flavor, odor, and texture ratings of freeze-dried Beef Stew over a 24-week storage period at 100° F and amounts of oxygen taken up by 125 grams of product.

Vacuum (Inches)	30				28				26				24				22				20				0			
Oxygen Available (ml)	6				15				27				36				45				58				161			
Time (Weeks)	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating
0	0	6.5	6.4	6.1	0	6.5	6.4	6.1	0	6.5	6.4	6.1	0	6.5	6.4	6.1	0	6.5	6.4	6.1	0	6.5	6.4	6.1	0	6.5	6.4	6.1
2	1	6.9	6.9	6.0	11	6.4	7.0	6.0	16	7.1	7.3	6.4	21	6.6	6.3	5.3	22	6.4	6.4	5.7	28	5.7	5.9	5.1	49	4.5	5.9	5.1
4	2	6.7	6.8	5.4	11	6.2	6.2	5.1	22	6.3	6.7	5.6	20	4.4	5.7	5.0	31	5.6	6.2	5.4	35	4.6	5.8	4.9	27	4.3	5.5	5.2
12	5	6.4	6.2	5.9	14	6.3	6.8	6.1	25	5.4	5.7	5.6	34	4.9	6.1	5.2	42	4.4	5.1	5.1	55	4.3	5.4	5.0	108	3.3	3.8	4.4
24	6	6.6	6.2	6.3	15	6.3	6.1	5.9	26	6.2	5.9	5.6	35	4.8	5.3	5.7	14	4.2	4.9	5.9	56	5.0	5.1	5.3	154	2.3	3.4	4.3

Table 4. Flavor, odor, and texture ratings of freeze-dried Chicken Stew over a 24-week storage period at 100° F and amounts of oxygen taken up by 125 grams of product.

Vacuum (Inches)	30				28				26				24				22				20				0			
Oxygen Available (ml)	9				16				21				35				46				59				151			
Time (Weeks)	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating	O_2 uptake (ml)	Flavor Rating	Odor Rating	Texture Rating
0	0	6.7	7.2	5.1	0	6.7	7.2	5.1	0	6.7	7.2	5.1	0	6.7	7.2	5.1	0	6.7	7.2	5.1	0	6.7	7.2	5.1	0	6.7	7.2	5.1
2	6	6.4	6.8	5.7	3	6.7	6.8	5.1	5	5.9	6.7	5.2	9	5.7	6.7	5.0	10	5.8	5.2	5.8	16	6.0	6.8	5.4	24	4.9	6.2	5.1
4	4	6.7	6.8	5.2	11	6.5	6.8	5.4	9	6.4	6.7	5.6	17	4.7	6.0	5.1	20	6.3	5.8	6.3	19	6.1	6.7	5.5	33	4.9	5.8	4.8
12	3	6.5	6.5	5.8	13	5.7	6.2	5.9	13	4.7	5.9	5.6	20	4.6	6.0	5.5	26	5.5	6.2	5.8	30	5.4	6.1	5.6	56	4.7	6.0	5.6
24	9	6.0	6.5	5.3	15	5.5	6.1	5.3	21	5.1	5.9	5.3	34	4.5	5.5	4.8	39	4.6	5.7	5.1	56	4.1	4.7	4.4	143	2.5	3.8	4.3

Table 5. Correlation coefficients (r) and regression equations for ml oxygen used versus the various panel ratings.

Variates	r Values	Regression Equation
Beef Stew		
Flavor rating	0.8518**	Y=6.46 - 0.032X
Odor rating	0.8789**	Y=6.65 - 0.024X
Texture rating	0.7322**	Y=5.84 - 0.012X
Chicken Stew		
Flavor rating	0.8301**	Y=6.17 - 0.030X
Odor rating	0.8233**	Y=6.64 - 0.022X
Texture rating	0.1932	

* $P > 0.05$ ** $P > 0.01$ DF = 27

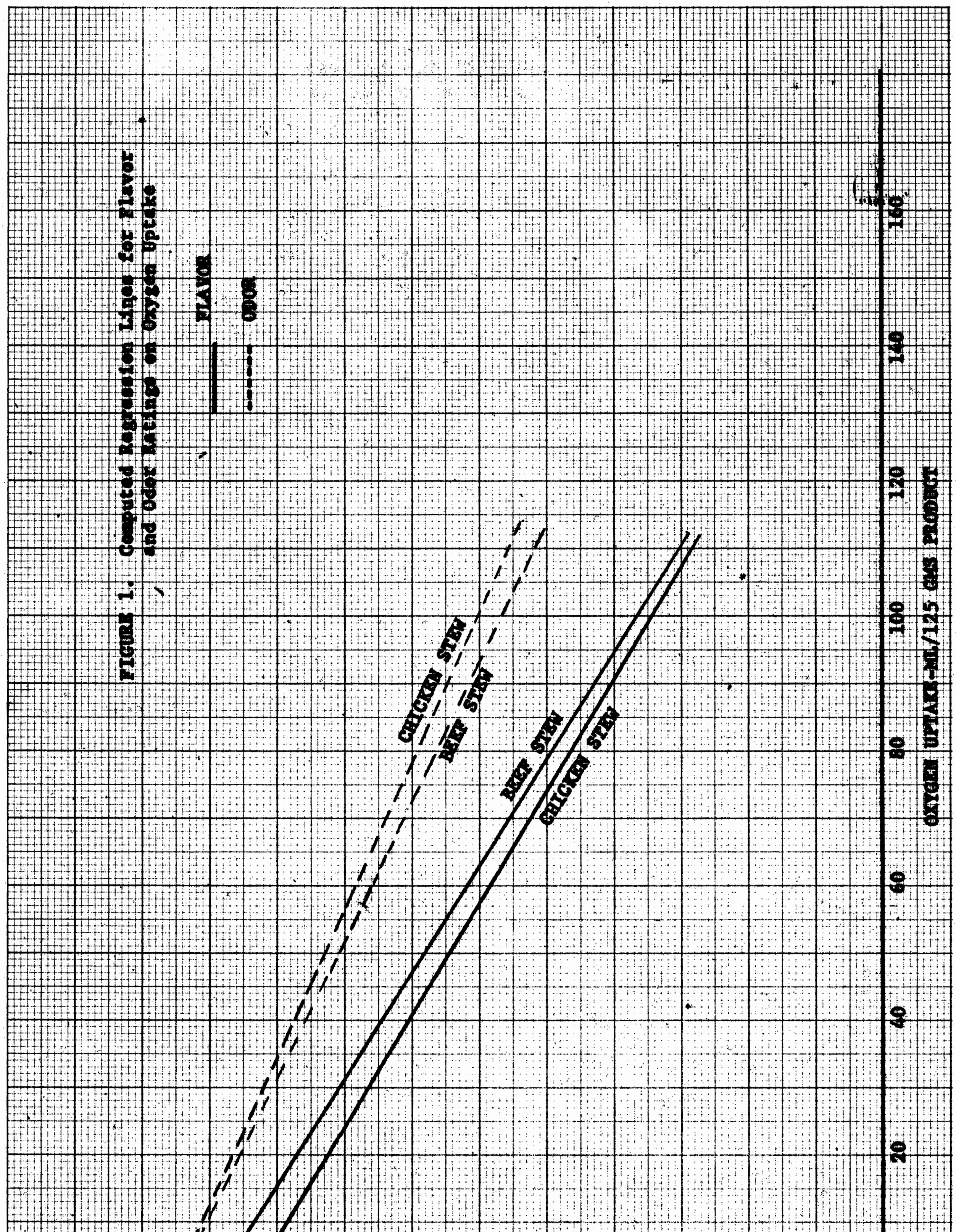

FIGURE 1. Computed Regression Lines for Flavor and Odor Ratings on Oxygen Uptake

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13. ABSTRACT

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Oxygen	6					
Headspace	0					
Freeze-Dried Foods	7					
Military Rations	4					
Freeze-Dried	0					